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The Network Centric Warfare Sensor Grid: A Short-Term Requirement

By

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Abstract

Network centric warfare (NCW) is a concept that may hold much future promise for the Navy. However, for a variety of reasons, NCW will not appear overnight. By 2010 the primary instruments of naval forward presence and power projection, the carrier battle group and the amphibious ready group/Marine Expeditionary Unit, will be remarkable not for how much they have changed but how much they resemble today's forces. While some specific capabilities may improve, composition will remain essentially the same. However, paradoxically, it is exactly because the Navy will remain dependent upon large platforms that an element of NCW needs to be brought to bear. Without an NCW-like sensor grid, naval platforms operating in the littoral of 2010 will be at far greater risk than they are today. While mines, anti-ship cruise missiles (ASCMs) and submarines are not new threats, the potential exists for them to become far more difficult for naval forces to contend with. Two scenarios dealing with choke-point transit show how, without a developed sensor grid, the Navy will have difficulty acquiring the information it needs to conduct safe passage. While the need for the sensor grid is evident, there are several obstacles which need to be overcome related both to the development of the grid and the actual sensors themselves.

Introduction

Network centric warfare (NCW) is a concept about which more and more is being written. One point regarding NCW that concept advocates stress is the value of a shift in importance away from platforms to networks. Despite this, naval forces by the year 2010, whether seen through the eyes of a cynic, skeptic, or true believer in NCW, will appear decidedly platform oriented. This poses a problem. As the Navy continues to evolve in its ability to operate in the littoral, the potential exists for the level of threat to increase at a far greater rate. Paradoxically, it will be precisely because of the Navy's continued reliance upon large, vulnerable platforms that an important element of NCW needs to be brought to bear. Only by divorcing sensors from large platforms and developing an NCW-like sensor grid can the Navy offset the risk associated with littoral operations in 2010.

To underpin this thesis, this paper shall first briefly describe the concept of NCW, comparing potential long-term advantages with short-term realities as regards force structure. Next will come a discussion of naval forces as they are likely to be in 2010, followed in turn by a description of the primary threats to those forces. With the anticipated line-ups thus set, two scenarios will be presented that will demonstrate U.S. vulnerability. Finally will come discussion of how an NCW-like sensor grid would solve the problem common to both scenarios, as well as what needs to be done to make the grid a reality.

NCW: Long-term benefits versus short-term realities.

First of all, what is NCW? It is a concept which, according to some, is "the way we will organize and fight in the information

age."[1] Central to the concept is "the ability of geographically dispersed forces (consisting of entities) to create a high level of shared battlespace awareness that can be exploited via self-synchronization and other network-centric operations to achieve commanders' intent."[2] This is achieved by effectively linking together sensors, actors (providers of combat power), and decision makers and provide to all a common and vastly increased battlespace awareness.[3] Such connectivity and increased awareness should allow the military "to move from an approach based upon the massing of forces to one based upon the massing of effects."[4]

There are many possible benefits of network centric warfare, spilling over into nearly every facet of military activity. From planning to damage assessment, network centric warfare would revolutionize each phase of military operations. Given the potential ability to mass effects, perhaps one of the most important implications would be in force structure. The level of firepower associated with a division or a carrier air wing may become available with a smaller, more distributed force. And with that force comes a shift in importance away from platforms.[5]

However, the promise of a smaller, less platform-dependent (and, thus, potentially less expensive) force remains in the short-term just that, a promise. The budgetary appeal of NCW notwithstanding, all the services continue to fund or plan on funding expensive weapons platforms. For the U.S. Navy, the F/A-18E/F, Land Attack Destroyer (DD-21 class) and Seawolf and Virginia class submarines will dominate the procurement budget. The bottom line is that, at least in the foreseeable future, naval forces will continue to look much as they do now. A glance at JV2010 reveals a bow-on shot of that platform of platforms, a

Nimitz class aircraft carrier. This is not a condemnation of either NCW or service programs, rather it is a reflection of current acquisition realities, enormous life-cycle costs, and money already spent. In 2010, the carrier battle group (CVBG) and the amphibious ready group with an embarked Marine Expeditionary Unit (ARG/MEU) will likely remain the essential components of naval forward presence and power projection.

The line-up versus the threat.

Of the CVBG, while capabilities may be improved, little will change in its composition by 2010. With an initial operational capability predicted for 2008, the Land Attack Destroyer (DD-21 class) will have just begun to hit the fleet, but it will be a long way from phasing out either Spruance (DD-963) class or Oliver Hazard Perry (FFG-7) class combatants, as it is intended to do. Likewise, though Seawolf and Virginia class submarines will be part of the inventory, the venerable Los Angeles class will still predominate. On the carrier flight decks of 2010, the only major changes will be the introduction of the F/A-18E/F (with the attendant phasing out of the F-14) and the retirement of the S-3B. Though the "Super Hornet" will possess, among other qualities, greater range than current F/A-18 models, carrier airwings will likely either remain reliant upon Air Force tanking to perform long range strikes, or continue to force battle groups to remain close to potential targets.

Of the ARG/MEU, while both platforms and capabilities will improve somewhat, dependence upon large platforms will remain constant. The arrival of the V-22 Osprey, San Antonio class LPD, and Advanced Amphibious Assault Vehicle will allow embarked

Marines to realize their vision of ship-to-objective maneuver at increased range. While, in theory, this will allow the ARG/MEU greater standoff, geographic realities in several important areas of the world will still mean operations in littoral regions.

However, as a platform centric force operating in the littorals in 2010, naval forces will be at far greater risk than today. While the U.S. Navy is evolving and refining its ability to operate in the littoral, potentially hostile nations could greatly improve their access denial capabilities. This is not lost on the current Chief of Naval Operations: "... countering a potential adversary's area denial efforts will become the single most crucial element in projecting and sustaining U.S. military power where it is needed."[6] Making the problem difficult are improvements to mines, anti-ship cruise missiles (ASCMs) and submarines (while tactical ballistic missiles will evolve into a serious threat, the ability to hit a moving target by 2010 is questionable).

The U.S. Navy's Achilles heel with regard to operations in the littoral is mine warfare. This is true historically, it is true today, and, unless something is done soon, it will be true in 2010. Fear of mines precluded amphibious landings at Wonsan in the Korean War as well as in Kuwait during Desert Storm.[7] Despite the comparative lack of glamor associated with mine warfare, enemy mines have accounted "for 14 of the 18 Navy ships destroyed or damaged since 1950."[8] Marine Major General Edward Hanlon, Jr, wrote, "...naval expeditionary forces can reasonably expect the already considerable problems created by naval mines to get worse long before they get better."[9]

With naval mines, the problem is three-fold. The first

problem is proliferation. As it stood in 1997, the Office of Naval Intelligence estimated that 50 countries around the world possessed over 150 types of mines.[10] This owes to the fact that mines can be inexpensive to buy and deploy. And even the simplest mine can be devastatingly effective: the moored contact mine that blew a 20 foot hole in Tripoli's hull during Desert Storm cost between $1,000 and $2,000.[11] This is "bang for the buck" at its best and makes mine warfare an inexpensive and effective access denial capability.

Second, beyond proliferation, increasing technological sophistication is a problem. Though older contact mines are still a problem, mines are designed today with defeating countermeasures in mind. Whether the mine incorporates multiple sensors, ship counting ability, or is shaped or coated in such a way as to deceive mine hunting sonar, newer technology makes countering the mine threat exponentially more difficult. By 2010, proliferation of even smarter, "stealthier" mines can be expected given the low cost of entry into this warfare area.

The third problem is that mine countermeasure warfare (MCM) is slow, difficult, and dangerous work. This would be true even if only combating simple contact mines. The problem is compounded with increased mine sophistication. While since the early 1990's the U.S. Navy has improved its MCM capabilities, in terms of both equipment and tactics, the threat has evolved as well, and at a greater rate. The Jane's defense information organization predicts flatly that, "Mine counter measures will continue to lag behind the development of the mine."[12]

But mine warfare is not the only serious near-term threat to U.S. ships in the littoral. Next in the order of cost-

effectiveness would be the anti-ship cruise missile (ASCM). Already 75 countries possess one or more of the 90 different types of ASCMs.[13] This is another area that is going to get worse before it gets better: Russia, France and China are actively exporting top line weapons. This means that the trend, even regarding potential third-world adversaries, is towards stealthier, faster, longer-range ASCMs with advanced seekers and more mobile launchers.[14] Making things worse, areas from which these new ASCMs might be launched could easily be defended by the latest in surface-to-air missiles (SAMs). For operations within sight of shore, a modern ASCM will pose a formidable threat.

Fortunately for U.S. naval forces, potentially hostile nations will still have to overcome a significant barrier to exploit modern ASCMs to their full potential. Without a bona fide over-the-horizon targeting (OTHT) capability, even modern ASCMs are a relatively short range threat. Use of sea, air, or land-based radar will still be limited by line of sight, jamming, or possible destruction. Though hand-held global positioning system (GPS) receivers and cellular phones are becoming widespread in their use and could constitute a rudimentary capability, an individual attempting to pass visual locating data will still remain vulnerable to operational deception, counter-measures, and environmental effects (for example, weather and darkness). By 2010 a true OTHT capability, able to pass accurate and timely targeting data, will still be beyond the reach of a great many nations.

The last major threat to naval operations in the littoral to discuss is the submarine. Despite the comparatively high costs associated with acquiring, maintaining and operating submarines,

44 countries currently possess them.[15] While nuclear-powered fast attack submarines (SSN) continue to be built, and countries as diverse as India and Brazil pursue acquiring them, it is the proliferation of the diesel-powered submarine (SS) that is of greater immediate concern.

This owes to the fact that, with regard to submarine warfare, the rules of the game have changed completely. The passive acoustic advantage enjoyed by U.S. forces over Soviet SSNs in the open ocean during the Cold War has been nullified by relatively quiet SSs operating in the noisy littoral environment: "Passive sonar is generally ineffective against a diesel submarine."[16] Before localization, tracking, classification and attack can occur, detection must take place and, "Mountains of evidence have been collected that prove non-acoustic sensors provide the majority of detections against diesel submarines, the primary sensor being the human eye of a pilot in a helicopter or fixed wing aircraft."[17] While the Navy is currently developing systems, such as Automatic Radar Periscope Detection and Discrimination (ARPDD), to take advantage of a diesel submarine's greatest disadvantage (being detected while snorkeling), the threat is about to change again.[18]

Current tactics and even systems under development (ARPDD for example) may prove inadequate in the face of the latest development in non-nuclear power plants: air independent propulsion (AIP). By increasing submerged endurance time by a factor of five (as Germany advertises for its developing AIP program, the Type 212), AIP will make even visual or radar detection far less likely.[19] Some estimate that an AIP submarine will need to surface only every 30-50 days[20] . This would mean

that near parity, in terms of both quietness and endurance, will have been achieved with current U.S. SSNs while operating in the littorals. While Sweden, with its Gotland class, is the only country currently using AIP, it is only a matter of time before this technology hits export markets. If Germany's export of its Type 212 in any way mirrors that of its highly successful Type 209, widespread proliferation can be expected.

But not only will these submarines be difficult to locate, they will be armed with greatly improved weapons. Russia's rocket powered, 200-knot Shkval torpedo is for sale internationally.[21] So, too, are improved, extended-range versions of both 53 and 65 centimeter torpedoes, including the wake-homing variety. Underwater weapons systems that were, until recently, closely guarded state secrets are on the market and their presence will greatly increase the risk of operations in littoral regions.

<u>The two scenarios.</u>

Thus, taken either separately or in combination, countering the threat associated with mines, ASCMs, and submarines will pose considerable challenges for naval forces in 2010. To illustrate this point, consider how transit of the Straight of Hormuz (SOH) might be affected. Doubtless, this heavily-transited choke-point will remain vital to U.S. interests in 2010. Just as certainly, barring major political changes, transit upon these waters will still be subject to the whim of a potentially hostile nation. While Iran can already menace operations in this area with mines, submarines, and ASCMs of the air, sea, and land launched varieties, the situation could be far more ominous by 2010. If Iran chooses to upgrade its mine-warfare, ASCM, or submarine (or

some combination of these) capabilities, they might well be able to close the SOH for an extended period. Discussion of two scenarios will make this point clear, highlighting the need for an NCW-like sensor grid.

First, to prevent the entry of U.S. naval forces into the Persian Gulf, Iran decides to mine the SOH. In 2010, as today, four options will present themselves to deal with this decision. Specifically, these options are to prevent the laying of the mines, either clear or avoid the mines once they have been placed in the water, or accept greater risk while doing nothing in terms of counter measures.[22]

Working against the first option, prevention, is the historical reluctance of the United States to strike preemptively. Though striking the mines while they are still in storage would be the best counter-measure available, this will not likely occur. The United States has almost without exception been willing to accept greater military risk, in the form of ceding time, as the trade-off to possibly being able to resolve a situation diplomatically. Examples of this tendency abound, from Pearl Harbor at the outset of World War II to the recent actions in Kosovo. In our scenario, history tells us that the Iranians, who are probably precipitating and therefore driving the situation, would probably have ample time to disperse their mines from storage facilities if not actually lay them. Simply moving the mines out of storage would be enough to reduce their vulnerability and eliminate prevention as a credible option.

Working against the last option, accepting greater risk while doing nothing, is the aforementioned platform dependence. This platform dependence hurts in two ways. First, at the operational

level, with each ship in a CVBG or ARG/MEU playing an important role, even one hit could possibly preclude the very operation the forces were sent to conduct. The cliche that, "every ship is a minesweeper - once" doesn't work well for a force that counts on a few relatively large platforms. Second, at the strategic level, while the effect would certainly depend of the circumstances, the potential loss of life associated with the loss of a ship may erode public support for further action. Thus, for both operational and strategic reasons, a "damn the torpedoes" approach without countering the threat is not a realistic alternative.

Clearing mines already in the water would be very problematic. Mine clearing operations break down into hunting, sweeping, or a combination of the two. Of these, "mine hunting is preferred because it gives a more complete and reliable search."[23] But hunting even "vintage" mines under the best of circumstances is time consuming and not 100% reliable. Iranian use of modern mines and the environmental conditions of the SOH itself would represent something far removed from ideal mine hunting conditions.

While the obvious solution to the problem of knowing where mines have been placed would be to conduct surveillance of mine laying operations, without an NCW-like sensor grid this would be very difficult for three reasons. First, with the volume of maritime traffic in the SOH and without adequate real-time cuing, knowing which vessels to observe might prove impossible. Second, if ships or aircraft were used, they could be vulnerable to Iranian ASCMs and SAMs, either land or sea based. Since Iran has already decided to commit a hostile act by mining, why should they be reluctant to attack surveillance platforms? Third, though

satellites might be able to conduct some of the surveillance, factors ranging from potentially long revisit times to atmospheric conditions preclude complete reliance upon these assets.

New large platform-based technologies currently in development aren't the answer either. Systems expected to be available by 2010 will not be able to solve the entire problem. For example, the Rapid Airborne Mine Clearance System (RAMICS), which will probably have reached initial operating capability, will only be of use against mines that are near the surface.[24] The same is true of the Magic Lantern System.[25] Other systems capable of locating deeper mines (toroidal volume or synthetic aperture sonar, for example) are only in early stages of development.[26]

Thus, even in the absence of any other threat, clearing Iranian mines would present a difficult choice. This would be either to allocate a great deal of time to perform a thorough search (which could still not guarantee 100% confidence and would greatly delay the transit) or give the suspected area a quicker look and accept the increased risk. While this risk could be offset somewhat by sweeping, sophisticated mines pose problems here as well. While sweeping doesn't require as specific a knowledge of mine location as hunting, mines, even of the sort available today, require multiple sweeps (in order to account for multiple sensors, ship counting ability, or both) and multiple sweeps means further delay.

Of even greater concern, if the areas chosen to be cleared are within range of modern ASCMs and SAMs, delayed transit is only an inconvenience compared to what else could happen. Without a developed NCW-like sensor grid, Iranian ASCMs and SAMs could severely curtail or even end mine clearing efforts altogether by

eliminating the U.S. Navy's limited and vulnerable mine clearing forces. Loss of the ability to clear mines would, by necessity, force the choice back to either accepting greater risk or stopping the show.

Avoidance is the only remaining option but it, too, depends on knowing exact mine locations. While the effort to merely locate mines need not be as exhaustive as that associated with clearing them, all of the difficulties brought to light in the discussion of mine hunting (problems with surveillance, reduced confidence, increased risk, and lost time) would apply here as well.

This first scenario points out the difficulties U.S. naval forces might encounter in dealing with sophisticated mines. By exposing naval forces to a credible ASCM and SAM threat as well, a negatively synergistic effect is created. Striking preemptively or doing nothing in the face of increased risk likely rule themselves out, leaving only avoidance and clearance (or, most likely, a combination of the two) as options. Critical to either is information: knowing where the mines are (or being able to asses where they are not) solves the lion's share of the problem. Information will be critical to the next situation as well.

In the second scenario, again to prevent U.S. naval forces from transiting, the Iranians have decided to place a recently acquired AIP submarine at the approaches to the SOH. The same four options present themselves for dealing with this threat and, for the same reasons, striking preemptively and accepting greater risk while doing nothing will be ruled out. This again leaves the options of avoidance and clearance, referred to in the world of under-sea warfare as sanitization and prosecution, respectively.

However, before prosecution can take place, detection must occur and herein lies a problem.

U.S. naval forces would be hard pressed or put at high risk to detect the Iranian submarine. As mentioned before, passive acoustic detection, whether by SSN, surface or air asset, will be very unlikely and, with greatly enhanced submerged endurance, visual or radar detection is improbable as well. This leaves, given the technologies that will be available in 2010, active sonar detection but this poses three problems. First, use of active sonar is considered a hostile act. As such, obtaining authorization for its use could be complicated. Second, the environmental conditions in the littorals sharply reduce detection ranges. This is important, first, because it complicates the problem for air platforms and, second, because it means that surface or subsurface platforms would only achieve detection once they were well within range of Iranian torpedoes. Complementing this is the third problem: use active sonar instantly makes the hunter the hunted by giving away location. For an SSN, the implications are obvious. The result would be a dual in which the Iranian submarine would have the advantage in knowing the threat line-of-bearing first. While an air asset using active sonar may not be at direct risk from the Iranian submarine (though the use of effective submarine launched SAMs might not be far into the future), Iranian possession of extended range, wake-homing torpedoes might mean having to prosecute in areas defended by land-based SAMs.

The problem of asset vulnerability applies as well to the option of sanitization. While outwardly the best choice, sanitization would still mean either placing an SSN or surface

combatant at risk of counter-detection or potentially putting air assets within range of SAMs.

Thus, as demonstrated in both scenarios, getting naval forces through the SOH in 2010 could represent a very tall order. Significant operational delay may be the best that can be hoped for and total exclusion might occur. Success in either scenario will hinge upon *knowing* exactly where the threat is, or at least in achieving a high level of confidence in where it is not.

<u>Where an NCW-like sensor grid fits in and what is needed.</u>

An NCW-like sensor grid is the only means by which such information could be reliably derived. Because of the protective umbrella provided by ASCMs and SAMs, large platforms, such as ships or aircraft, cannot not be counted upon to provide adequate surveillance of mine laying. This means locating efforts will be required that steal time and place U.S. forces at risk. Likewise, with regard to the submarine threat, attempts to prosecute or sanitize make U.S. platforms vulnerable to counter-detection or SAMs. Instead of using platforms to confront either threat directly, the answer lies in tying together sensors that are some combination of less obviously intrusive, less vulnerable and less expensive (and therefore more abundant) to provide the required threat locating information. Some of these sensors are currently available but require either more complete integration, further expansion of capability, or both. Other sensors need more complete development, as does the supporting grid itself.

Satellites and Special Operations Forces (SOF) represent examples of current sensor capabilities that require more complete integration. While neither of these capabilities represent a full

answer to the problem, both can provide cuing data and in a mutually supporting way. With information as to which vessels to observe, or at what time the submarine left port, the job of the other sensors down the road is made much easier. However, this presupposes that this cuing information is disseminated to those who need it in a timely manner.

Human Intelligence (HUMINT) is an example of an existing capability that needs to be expanded and integrated into the grid. While, again, HUMINT might not be able to do the entire job, it too could provide valuable information relevant to the two scenarios. By providing information as to the type and number of mines, the ports or even vessels to which they have been sent, the disposition of ASCM and SAM batteries, or the submarine's intentions, HUMINT can focus and increase the efficiency of surveillance efforts. The issue, again, is ensuring that this information is quickly placed in the hands of those who can use it.

Sensors or capabilities that need to be developed fall generally into two categories, those that support the workings of the grid itself and those that will help perform the actual surveillance. Of the former, while steps have been taken to realize an information network (the Secret Internet Protocol Router Network and Joint Deployable Intelligence Support System, for example) much of what passes for "sensing" today is tied together in more time-honored ways: voice-radio or stand-alone data links (the venerable "purple" net and Link-11, for example). Though the Joint Maritime Command Information System (JMCIS) is in place, it does not allow for real time tactical displays and the other services use different systems. A real sensor grid must be

common to all services and be capable of automating sensor input. It must also be made impervious to compromise.

Of the sensors needed to conduct the actual surveillance, they may be closer at hand than the backbone of the grid. While total battlespace awareness won't be achieved by 2010, "with integrated circuits, laser emitters, and detectors growing cheaper by the year, sensors grow increasingly cost effective."[27] Sensor capabilities that could solve the problems associated with the two scenarios are well into development and their initial operating capabilities need to be expedited.

With regard to the problem of mine laying surveillance, unmanned aerial vehicles (UAVs) could be the answer. While the large UAVs of today (Global Hawk and Dark Star for example) would still be vulnerable, much smaller UAVs would not be. Of such UAVs, the Naval Research Laboratory has already built a remarkable specimen: capable of carrying a one-kilogram payload, the Sender might soon be able to remain aloft for 10 hours and come at a unit cost of $4,000 (if purchased in the thousands).[28] Even when mated with a small GPS receiver and an optical system capable of ranging, the system would be far less expensive, not to mention far less vulnerable, than current surveillance assets. A fleet of small, inexpensive, low-observable UAVs, that can provide image and location data to a functioning network would solve the surveillance problem and provide the information necessary either to avoid or more efficiently hunt mines in the SOH.

Once mines are in the water, unmanned underwater vehicles (UUV) can help maintain large-platform standoff. Two programs in development, the Remote Minehunting System and the Near-Term Mine Reconnaissance System, plan on using UUVs from surface combatants

and submarines, respectively.[29] The problem is that, "The Navy has not decided on the mix of on-board and special purpose forces it wants...and committed the funding needed for developing and sustaining those capabilities."[30] Prioritization needs to be given to UUV development, as it could help in both scenarios.

In somewhat the same manner, UUVs could solve the detection and sanitization problems presented in the second scenario. In this case, UUV active sonar units could be sent in advance of the CVBG or ARG/MEU to detect or sanitize while the major combatants remain beyond torpedo range. Admittedly, use of UUVs would require advances in underwater acoustic communications to enable high data throughput and avoid jamming or exploitation. Further, use of active sonar still would require authorization. But with the threat level rising, clearly the use of such a system would be of great benefit and deserves much attention.

In conclusion and as illustrated in the two scenarios, an NCW-like sensor grid is the best way to assure continued access to the littorals in the face of the potential threats of 2010. Though such a grid might also serve to enhance mission effectiveness, access must obviously come first. While there are developmental and, perhaps, even cultural issues to overcome, realization of such a grid is largely possible and greatly needed if for no other reason than to ensure the viability of naval platforms in the chosen operational environment.

Notes

[1] David Alberts and others, Network Centric Warfare (Washington: DoD C4ISR Cooperative Research Program, 1999), 2.

[2] Ibid., 8.

[3] Ibid., 116.

[4] Ibid., 90.

[5] Chief of Naval Operations Admiral Jay Johnson, quoted in David Alberts and others, Network Centric Warfare (Washington: DoD C4ISR Cooperative Research Program, 1999), 233.

[6] Jay Johnson, "Anytime, Anywhere: A Navy for the 21st Century", U.S. Naval Institute Proceedings, November 1997, 49.

[7] H. Lyons and others, The Mine Threat: Show Stoppers or Speed Bumps? (Alexandria VA: Center for Naval Analyses, 1993) 1.

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[9] Edward Hanlon Jr., "Think or Sink - 21st Century Mine Warfare", Surface Warfare, May/June 1998, 2.

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[12] Anthony Watts, Jane's Underwater Warfare Systems 1998-1999, (Surrey, U.K.: Sentinal House 1998) 285.

[13] Challenges to Naval Expeditionary Warfare, 7.

[14] Ibid., 9.

[15] Watts, 11.

[16] Shawn T. Nisbett, "The Impact of Modern Radar Technology on Submarine Tactical Employment," The Submarine Review, January 2000, 71.

[17] Ibid., 72.

[18] Ibid.

[19] Watts, 17.

[20] John Vlattas, "Shifting From Blue to Brown: Pursuing the Diesel Submarine Into the Littoral," The Submarine Review, April 1999, 93.

[21] Watts, 216.

[22] Lyons and others, 15.

[23] Ibid., 17.

[24] Department of Defense, Defense Technology Objectives for the Joint Warfighting Science and Technology Plan and the Defense Technology Are Plan (Washington: 1999), I-122.

[25] GAO/NSIAD-98-135, 14.

[26] Department of Defense, I-123.

[27] Martin Libicki, McNair Paper 61, Illuminating Tomorrow's War (Washington: U.S. Government Printing Office 1999), 8.

[28] Ibid., 27

[29] GAO/NSIAD-98-135, 14-15.

[30] Ibid., 3.

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